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Racial, Ethnic, and Age Differences in the Incidence and Survival of Childhood Cancer in Oklahoma, 1997-2012

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Abstract

While cancer is relatively rare in children under 20, it is the leading cause of disease-related death among children aged 5 to 14 years. We aimed to describe the incidence and survival of childhood cancer in Oklahoma from 1997-2012. We calculated age-adjusted incidence rates and five-year observed survival by cancer type using Oklahoma Central Cancer Registry and Surveillance, Epidemiology, and End Results program data among children diagnosed with cancer under the age of 20 from 1997-2012. The average annual age-adjusted incidence rate of childhood cancer was 168.9 per million for the US and 171.7 per million for Oklahoma. Overall, Oklahoma had lower survival from childhood cancer compared to the US (77.0% v. 80.6%). In recent years, research has been conducted on the epidemiology of childhood cancer. Little research has been done, however, on the incidence or survival of childhood cancer at state levels and none focused exclusively on Oklahoma.

Introduction

Cancer is relatively rare in children under 20, with an estimated 10,380 new cases in the United States (US) expected to be diagnosed in 2015.[1] However, it is the leading cause of disease-related death among children aged 5 to 14 years.[2] Risk factors vary by cancer type

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and many of the proposed risk factors have limited or insufficient evidence to evaluate causality.[3] More extensive research has been conducted on the most frequently diagnosed types of childhood cancers, including leukemia, lymphoma, and brain/central nervous system (CNS) tumors. For acute lymphocytic leukemia (ALL), known risk factors include age, gender, higher socioeconomic status (SES), race/ethnicity, in-utero or postnatal exposure to ionizing radiation, and several genetic conditions including Down syndrome. These factors meet most or all criteria for causality detailed in the review.[3] For acute myeloid leukemia (AML), known risk factors are similar to those of ALL and include race/ethnicity, previous exposure to chemotherapy agents, ionizing radiation, and several genetic conditions including Down syndrome.[3] Ionizing radiation, stronger in AML than ALL, is the only established environmental risk factor for acute leukemia.[4] Known risk factors for Hodgkin's lymphoma include family history of Hodgkin's lymphoma, Epstein-Barr virus infection, higher SES for older children and lower SES for younger children, along with fewer social contacts in early childhood.[3,5,6] For childhood brain and CNS tumors, known risk factors are limited but include gender, therapeutic doses of ionizing radiation to the head, and several genetic conditions including neurofibromatosis.[3,7]

Until the first chemotherapy treatments were introduced in 1948 by Dr. Sydney Farber, known as the Father of Modern Chemotherapy, leukemia was essentially a death sentence with no available treatments.[8,9] The survival of childhood leukemia continued to be poor until the 1970s, when improved treatments became available.[10] Currently, the five-year relative survival rate of all childhood cancer is approximately 83% in the US, ranging from 58% for some brain tumors to over 90% for Hodgkin lymphoma and retinoblastoma.[11]

While many studies have described the epidemiology of childhood cancer in the US,[3,12,13] this is the first in Oklahoma. The purpose of this study was to describe the differences in incidence and survival of cancers in Oklahoma diagnosed among children and adolescents under 20 years of age compared to the US from 1997 through 2012. In order to get a clearer understanding of both the incidence and survival of childhood cancer by race/ethnicity and age, we further explored the three most common types of childhood cancer: ALL, astrocytoma, and Hodgkin lymphoma.

Methods

Data for both incidence and survival were collected from the Oklahoma Central Cancer Registry (OCCR), which has collected data on cancers diagnosed in Oklahoma residents since January 1, 1997.[14] We included children diagnosed with childhood cancer prior to 20 years of age between 1997 and 2012 who resided in Oklahoma at the time of cancer diagnosis. In our analyses by cancer type, we classified cancers according to the International Classification of Childhood Cancers.[15]

We classified children by age at cancer diagnosis as <1 year of age, 1-4 years, 5-9 years, 10-14 years, and 15-19 years. To evaluate incidence and survival by race/ethnicity, we classified children according to their primary race/ethnicity in the OCCR. All Oklahoma data are linked with Indian Health Service (IHS) records in order to decrease racial misclassification of American Indians/Alaska Natives (AI/AN). Due to small numbers,

analyses by race/ethnicity did not include Asian/Pacific Islander children. Results of this analysis are reported for white non-Hispanic (NH), African American NH, AI/AN NH and Hispanic children.

To calculate the incidence of childhood cancer in Oklahoma, we used the population estimates for 1997-2012 based on the US Census, resulting in average annual incidence rates per million for Oklahoma from 1997-2012. To age-adjust the incidence rates, we used the US 2000 standard million. We also calculated 95% confidence intervals (CI) for the crude and age-adjusted incidence rates using the formulae provided in Greenland and Rothman.[16] We calculated overall age-adjusted, age-specific, and age-adjusted race-specific incidence rates for the three selected childhood cancers in Oklahoma and compared these results with the Surveillance, Epidemiology, and End Results (SEER) estimates for childhood cancers from 1997-2012 using SEER*Stat software v. 8.2.1.[17] To compare incidence by age and race/ethnicity between Oklahoma and the US, we calculated rate ratios (RR) and 95% CIs.

We calculated five-year observed survival proportions for Oklahoma children diagnosed between 1997 and 2008 in order to have more complete five-year follow-up through November 1, 2014, which was the last date of follow-up for the OCCR data. We calculated survival time as the time to death or the end of the study (November 1, 2014). The OCCR periodically conducts follow-up of those included in the registry, along with linkage with the Oklahoma Mortality Data, the Social Security Death Index, and the National Death Index (NDI) to identify those who are deceased. We used Kaplan-Meier survival analysis to calculate observed survival and 95% CIs at five years after diagnosis among children 0-19 years at cancer diagnosis. The survival proportions were calculated for all age groups and each race/ethnicity analyzed in the incidence section. We used SEER*Stat to obtain national five-year observed survival proportions by age and race/ethnicity from 1997-2008 for comparison with Oklahoma data. However, SEER did not report survival for AI/AN separate from Asian/Pacific Islanders or for Hispanic children, so these results include the racial categories of white and African American.

We used SAS v. 9.4 for all Oklahoma analyses of incidence and survival. We used an alpha of 0.05 for all analyses. This study was approved by the institutional review boards at the University of Oklahoma Health Sciences Center and the Oklahoma State Department of Health.

Results

Incidence

The average annual age-adjusted incidence rate (AAIR) of childhood cancer was 168.9 per million for the US (95% CI: 167.0, 170.8) and 171.7 per million for Oklahoma (95% CI: 165.4, 178.1) from 1997-2012 (Table 1). While Oklahoma AAIR of specific cancer types was similar to that in the US for most cancer types, there were a few differences of note. Oklahoma had a lower AAIR of non-Hodgkin lymphomas (excluding Burkitt lymphoma), other gliomas, retinoblastoma, malignant gonadal germ cell tumors (in addition to an overall lower AAIR of germ cell/trophoblastic tumors/neoplasms of gonads), and thyroid carcinomas compared to the US. However, Oklahoma had a higher AAIR for miscellaneous

lymphoreticular neoplasms and fibrosarcomas/peripheral nerve/other fibrous tumors compared to the US. Overall CNS tumors were also elevated in Oklahoma, driven primarily by higher AAIRs of both specified and unspecified intracranial/intraspinal neoplasms compared to the US. Furthermore, overall other/unspecified malignant neoplasms were elevated, driven by other unspecified malignant tumors in Oklahoma compared to the US.

The three most common types of cancer in Oklahoma and the US during this time were ALL (OK AAIR: 32.5 per million; SEER AAIR: 34.7 per million), astrocytoma (OK AAIR: 13.0 per million; SEER AAIR: 14.0 per million), and Hodgkin lymphoma (OK AAIR: 10.8 per million; SEER AAIR: 12.0 per million). When evaluating each of these specific cancers by age, there were no significant differences between the age-specific incidence rates in Oklahoma and the US (Table 2). For ALL, the incidence was highest in children aged 1-4 years and generally decreasing in older age groups. The incidence of astrocytoma was also higher among children aged 1-4 and 5-9 years, whereas the incidence of Hodgkin lymphoma increased with age, with no cases observed among children under 1 year of age in Oklahoma or the US. While not significant, the age-specific incidence rate for Hodgkin lymphoma in Oklahoma was lower for children 5-9 years and 10-14 years of age at diagnosis compared to the US.

Although there were no significant differences by race/ethnicity between the US and OK for ALL, the AAIR for AI/AN NH was 22% higher in Oklahoma than the US (95% CI: 0.90, 1.65) (Table 3). However, the AAIR for astrocytoma was 21% lower among white children in Oklahoma compared to the US (RR: 0.79, 95% CI: 0.67, 0.94). Although not significant, the AAIR for astrocytoma for Hispanic children was 41% higher in Oklahoma compared to the US (RR: 1.41, 95% CI: 0.94, 2.11). In Hodgkin lymphoma, the AAIR for AI/AN NH children was 3.78 times greater in Oklahoma compared to the US (95% CI: 1.48, 9.67). Though not significantly different, the AAIR was 17% lower for white NH children (RR: 0.83, 95% CI: 0.67, 1.02) and 50% lower for African American NH children (RR: 0.50, 95% CI: 0.21, 1.23), but 40% higher for Hispanic children (RR: 1.39, 95% CI: 0.76, 2.54) in Oklahoma compared to the US.

Survival

In Oklahoma, the five-year observed survival of all childhood cancer was 77.0% (95% CI: 75.2%, 78.9%), which was significantly lower than the US at 80.6% (95% CI: 80.2%, 81.0%) (Table 4). Based on 95% CIs, we observed significant differences in survival for certain CNS tumors, neuroblastoma, and nephroblastoma (Wilms' Tumor). While survival in Oklahoma was significantly lower for astrocytoma compared to the US (71.6% v. 83.1%, respectively), survival for other specified intracranial/intraspinal neoplasms (OK: 89.4%, US: 67.7%) and unspecified intracranial/intraspinal neoplasms (OK: 95.2%, US: 38.1%) was significantly higher in Oklahoma compared to the US. Survival for neuroblastoma (OK: 58.4%, US: 73.6%) and Wilms' Tumor (OK: 77.4%, US: 89.1%) was also lower in Oklahoma compared to the US.

Patterns of survival by age differed for each cancer type, although the trends were similar between Oklahoma and the US with the exception of astrocytoma (Figure 1). For ALL, survival was lowest in children under 1 year in both Oklahoma and the US and highest

among children aged 1-4 and 5-9 years at diagnosis, which decreased among those 10-14 and 15-19 years of age, with similar estimates for Oklahoma and the US. For those with astrocytoma, Oklahoma was similar to the US for all age groups except children aged 15-19 years (OK: 48.7%, 95% CI: 33.0%, 64.4%; US: 76.0%, 95% CI: 72.7%, 79.3%). There were too few children to calculate survival for children under 1 year of age in Oklahoma. Among those with Hodgkin lymphoma, there were no children under 1 year of age in Oklahoma or the US or children from 1-4 years in Oklahoma. Among each age group, survival was near or greater than 90% in both Oklahoma and the US.

Regarding survival by race/ethnicity, SEER data were not available for AI/AN or Hispanic children for the selected diagnoses of ALL, astrocytoma, and Hodgkin lymphoma (Table 5). In Oklahoma, five-year observed survival for ALL was highest in Hispanic (92.0%), white NH (86.0%), and AI/AN NH children (82.0%), but lowest in African American NH children (70.8%); however, the 95% confidence intervals overlapped and were imprecise. In the US, the five-year observed survival for white children (regardless of Hispanic ethnicity) with ALL was 85.7% (95% CI: 84.9%, 86.5%) and for African American children was 80.4% (95% CI: 77.3%, 83.5%). Among children with astrocytoma, African American NH children had a five-year observed survival of 50% and Hispanic children had a survival of 62.5%, compared to 73.4% among white NH children and 87.5% among AI/AN NH children in Oklahoma. Again, the 95% CIs were imprecise and overlapped. SEER data indicated survival of 84.7% (95% CI: 83.3%, 86.1%) for white children and 73.5% (95% CI: 69.0%, 78.0%) for African American NH children in the US. Among children with Hodgkin lymphoma in Oklahoma, survival was 83.3% for African American NH children, 91.8% for white NH children, 94.4% for AI/AN NH children, and 100% for Hispanic children. In SEER, the survival was over 94% for both white (95.9%, 95% CI: 95.1%, 96.7%) and African American children (94.1%, 95% CI: 91.6%, 96.6%).

Discussion

Overall, trends for incidence and survival were similar between the US and Oklahoma, with increases in some tumor types and decreases in others. The most striking difference was the higher AAIRs of other specified and unspecified intracranial/intraspinal neoplasms in Oklahoma compared to the US. However, the survival for these tumors was also higher in Oklahoma compared to the US. One possible explanation is difference in classification of CNS tumors in Oklahoma, but this needs further investigation to confirm. Survival from neuroblastoma and Wilms' Tumor were also significantly lower in Oklahoma compared to the US; however, these tumors are rare and the estimates were imprecise.

The incidence of Hodgkin lymphoma in Oklahoma AI/AN NH children was significantly higher than that in US AI/AN children based on 95% CIs. Although intended to be nationally representative, SEER data may not be representative of all AI/AN populations in the US as SEER primarily reflects the AI/AN population in New Mexico and Alaska, which could explain the observed difference. The Cherokee Nation Registry, located in Northeastern Oklahoma, is included in SEER, but not in the publicly-available files for analysis.[18]

Although the underlying cause of ALL is unknown, there are many hypotheses as to why there are differences in incidence between ages and race/ethnicities. A reported age peak in childhood ALL occurs between ages 2 and 5, especially in white children.[19] Studies have hypothesized that because of the young age of many children with ALL, exposure may occur in-utero.[20-22] We observed no clear trend in the incidence of astrocytoma by age at the state or national levels, but Gurney, Smith, and Bunin[23] reported two age peaks of astrocytoma; one peak around age 5 and another at age 13 using SEER data from 1986-1994. Percy, Smith, Linet, Ries, and Friedman[24] reported age as a risk factor for Hodgkin's lymphoma in children and both Oklahoma and U.S. data confirmed this finding. Percy et al.[24] observed that the increased risk by age was present regardless of race/ethnicity. Furthermore, Cartwright and Watkins[25] stated that the incidence of Hodgkin's lymphoma peaks during two age groups, from 15-34 and over 60 years. This trend is present in more developed and urbanized countries, such as the U.S., indicating a relationship with socioeconomic status.[25]

The incidence rates of both ALL and Hodgkin lymphoma were lower among African American compared to white children in an analysis of combined National Program of Cancer Registries and SEER registry data from 2001-2009.[26] In a study comparing the incidence rates of childhood cancer for Alaska Natives to white children from SEER, Lanier et al.[27] observed no differences for ALL or astrocytoma among Alaska Native children compared to US white children. Smith et al.[28] reported that the lower incidence of in ALL in African American children was largely due to the lack of a pronounced age peak in this group. Moreover, Linet, Wacholder, and Zahm[29] reported that the low incidence in African American children may be due to genetic or environmental factors. Swensen, Ross, Severson, Pollock, and Robison[19] reported that there were significant differences between white and African American children with ALL regarding socioeconomic status. Regarding racial/ethnic differences for astrocytoma, Gurney et al.[23] stated that differences between race/ethnicities may be due to access to care. Improvements in the quality of diagnostic tests, such as Magnetic Resonance Imaging, and improved surgical diagnostic techniques have increased the incidence of childhood brain tumors through earlier diagnosis. Children without access to these diagnostic techniques may be diagnosed later typically resulting in lower survival.[30] Regarding Hodgkin lymphoma, Percy et al.[24] reported that the age-specific incidence for white and African American children was similar among children under 10 years, but a higher incidence among white compared to African American in older children (10-19 years), which we were unable to confirm due to small numbers.

Regarding age, survival for ALL was lowest among children under 1 year of age in Oklahoma and the US, which is almost entirely due to a rearrangement of 11q23 (MLL gene), which in more common in infants compared to older children.[31] Metzger et al.[32] reported that adolescents with Hodgkin's lymphoma tend to have poorer survivability than younger children. Bleyer et al.[33] reported that adolescents aged 15-19 were less likely to be included in cancer trials than children from 10-14 years, which may adversely affect their outcome, since participating in trials has been shown to have many benefits, including better survival. Because Hodgkin's lymphoma is more common in adolescence, participation in cancer trials is an important factor for this cancer.[33] The authors stated that approximately 75% of adolescents aged 15-19 were more often treated in adult cancer centers where

participation in clinical trials is lower than that in children's centers. Possible reasons for lower participation were the difficulty of treating adolescent cancers in an adult center where pediatric clinical trials may not be available, along with participating in a clinical trial and reluctance of both parents and adolescents to be treated at a childhood center.[33]

There were several possible reasons for apparent differences in survival for the selected childhood cancers between race/ethnicity groups. One is that the small number of cases in each age group and race/ethnicity, which decreased the precision of the estimate. Another could be due to unequal access to care and quality of care among minority races/ethnicities. Studies have observed that racial minorities, including African Americans, AI/ANs, and Hispanics, had lower survival, which may be due to access to care and adherence to therapy over a long period of time.[34-36] Specifically for ALL, African American children, especially those between years 1 and 9, tend to have lower survivability due to poor prognostic factors.[34,36,37] Metzger et al.[32] observed that African American children had similar clinical characteristics of Hodgkin lymphoma compared to white children, but lower socioeconomic status. While five-year relative survival was similar between the race/ethnic groups, treatment failure was higher among African American children compared to white children.[32] Evidence is limited regarding survival differences by race/ethnicity of astrocytoma, with one study observing no differences.[38]

An advantage of this study was the ability to include cases of childhood cancer from high quality population-based registries in Oklahoma and the US. Furthermore, Oklahoma has a high proportion of AI/ANs compared to the US (9.0% v. 1.2%, respectively), which allowed us to describe the three selected childhood cancers among this underrepresented group.[39] This was also the first descriptive study of childhood cancer epidemiology in Oklahoma, which allows for hypothesis generating for future studies.

One of the limitations of this study was the small sample size. Even combining 16 years of data in Oklahoma, we were unable to analyze the majority of childhood cancer types by age and race/ethnicity or examine time trends. The rarity of childhood cancer was evidenced by the wide 95% CIs for survival estimates by age and race/ethnicity, which may result in failing to detect true differences in the survival proportions between Oklahoma and the US.

Another limitation of this study was our assumption regarding follow-up time in the registry. OCCR regularly conducts follow-up of those included in the cancer registry and links with the NDI to determine vital status. However, this linkage was not completed each year at OCCR, but the majority of cases were updated with Oklahoma Mortality Data and the Social Security Death Index to identify those who are deceased. This may artificially inflate survival in more recent years and trends should be closely monitored. Furthermore, we assumed that children were alive through the end of the study period if they were not classified as deceased, but some misclassification may be present due to reporting delays, which may result in an overestimate of survival. However, the presumed alive methodology used by the OCCR results in similar survival estimates as SEER data, which conducts active follow-up.[40,41]

In recent years, much research has been conducted on the epidemiology of childhood cancer, especially at national and international levels. Little research has been done, however, on the incidence or survival of childhood cancer at state levels and none focused exclusively on Oklahoma. While there are many obstacles to studying such a rare disease, it is important to understand the burden of childhood cancer in Oklahoma in order to better understand risk factors, etiology, and the overall health of the state, which may lead to future prevention strategies.

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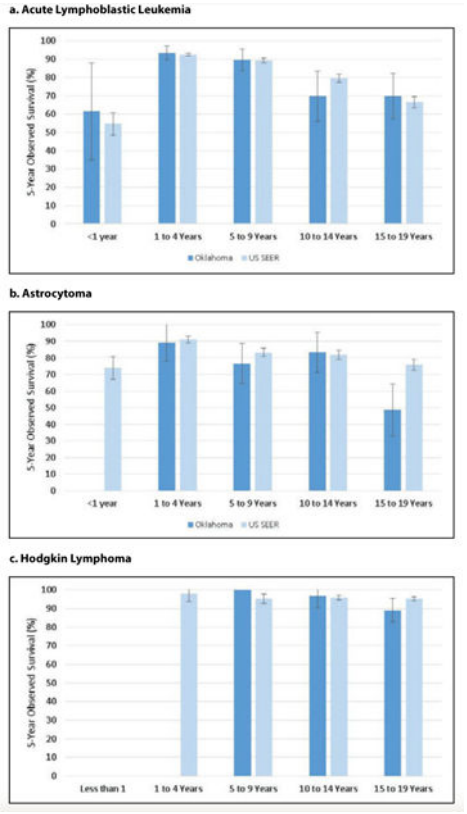

Figure 1. Five-year observed survival (95% confidence intervals) for acute lymphoblastic leukemia, astrocytoma, and Hodgkin lymphoma by age group in Oklahoma and the US, 1997-2012

Table 1

Average annual age-adjusted incidence rates per million person-years of childhood cancers and 95% confidence intervals from 1997-2012[a]

	Oklahoma[b]		SEER[c]	
Cancer Type	**N**	**Incidence Rate (95% CI)**	**N**	**Incidence Rate (95% CI)**
Total[d]	2797	171.7 (165.4, 178.1)	30506	168.9 (167.0, 170.8)
I Leukemias, myeloproliferative & myelodysplastic diseases	735	45.4 (42.1, 48.7)	8212	45.4 (44.4, 46.4)
I(a) Lymphoid leukemias	524	32.5 (29.7, 35.2)	6271	34.7 (33.8, 35.5)
I(b) Acute myeloid leukemias	139	8.5 (7.1, 9.9)	1506	8.3 (7.9, 8.8)
I(c) Chronic myeloproliferative diseases	34	2.1 (1.4, 2.8)	198	1.1 (1.0, 1.3)
I(d) Myelodysplastic syndrome/other myeloproliferative	11	0.7 (0.3, 1.1)	52	0.3 (0.2, 0.4)
I(e) Unspecified and other specified leukemias	27	1.6 (1.0, 2.3)	185	1.0 (0.9, 1.2)
II Lymphomas and reticuloendothelial neoplasms	361	22.1 (19.8, 24.4)	4376	24.4 (23.7, 25.1)
II(a) Hodgkin lymphomas	179	10.8 (9.3, 12.4)	2158	12.0 (11.5, 12.5)
II(b) Non-Hodgkin lymphomas (except Burkitt lymphoma)	111	6.8 (5.6, 8.1)	1600	8.9 (8.5, 9.4)
II(c) Burkitt lymphoma	38	2.4 (1.6, 3.2)	435	2.4 (2.2, 2.7)
II(d) Miscellaneous lymphoreticular neoplasms	22	1.3 (0.8, 1.9)	118	0.6 (0.5, 0.8)
II(e) Unspecified lymphomas	11	0.7 (0.3, 1.1)	65	0.4 (0.3, 0.5)
III CNS and misc intracranial and intraspinal neoplasms	563	34.8 (31.9, 37.7)	5145	28.5 (27.8, 29.3)
III(a) Ependymomas and choroid plexus tumor	46	2.8 (2.0, 3.7)	457	2.5 (2.3, 2.8)
I II(b) Astrocytomas	210	13.0 (11.3, 14.8)	2523	14.0 (13.5, 14.6)
III(c) Intracranial and intraspinal embryonal tumors	113	7.0 (5.7, 8.3)	1138	6.3 (5.9, 6.7)
III(d) Other gliomas	61	3.8 (2.8, 4.7)	900	5.0 (4.7, 5.4)
III(e) Other specified intracranial/intraspinal neoplasms	97	6.0 (4.8, 7.1)	81	0.4 (0.4, 0.6)
III(f) Unspecified intracranial and intraspinal neoplasms	36	2.2 (1.5, 3.0)	46	0.3 (0.2, 0.3)
IV Neuroblastoma and other peripheral nervous cell tumors	127	7.8 (6.4, 9.1)	1443	7.9 (7.5, 8.3)
IV(a) Neuroblastoma and ganglioneuroblastoma	123	7.5 (6.2, 8.8)	1396	7.6 (7.2, 8.0)
IV(b) Other peripheral nervous cell tumors	<5	N/A[e]	47	0.3 (0.2, 0.3)
V Retinoblastoma	33	2.0 (1.3, 2.7)	624	3.4 (3.1, 3.7)
VI Renal tumors	124	7.6 (6.3, 9.0)	1141	6.3 (5.9, 6.6)
VI(a) Nephroblastoma/other nonepithelial renal tumors[f]	115	7.1 (5.8, 8.4)	1035	5.7 (5.3, 6.0)
VI(b) Renal carcinomas	5	0.3 (0.0, 0.6)	105	0.6 (0.5, 0.7)
VI(c) Unspecified malignant renal tumors	<5	N/A[e]	<5	N/A[e]
VII Hepatic tumors	44	2.7 (1.9, 3.5)	449	2.5 (2.2, 2.7)
VII(a) Hepatoblastoma	28	1.7 (1.1, 2.3)	329	1.8 (1.6, 2.0)
VII(b) Hepatic carcinomas	15	0.9 (0.5, 1.4)	117	0.7 (0.5, 0.8)
VII(c) Unspecified malignant hepatic tumors	<5	N/A[e]	<5	N/A[e]
VIII Malignant bone tumors	147	9.0 (7.6, 10.5)	1532	8.5 (8.1, 9.0)
VIII(a) Osteosarcomas	78	4.8 (3.7, 5.9)	889	5.0 (4.6, 5.3)

	Oklahoma[b]		SEER[c]	
Cancer Type	**N**	**Incidence Rate (95% CI)**	**N**	**Incidence Rate (95% CI)**
VIII(b) Chondrosarcomas	<5	N/A[e]	62	0.3 (0.3, 0.4)
VIII(c) Ewing tumor and related sarcomas of bone	54	3.3 (2.4, 4.2)	482	2.7 (2.5, 2.9)
VIII(d) Other specified malignant bone tumors	<5	N/A[e]	78	0.4 (0.3, 0.5)
VIII(e) Unspecified malignant bone tumors	8	0.5 (0.2, 0.8)	21	0.1 (0.1, 0.2)
IX Soft tissue and other extraosseous sarcomas	210	12.8 (11.1, 14.6)	2189	12.1 (11.6, 12.7)
IX(a) Rhabdomyosarcomas	67	4.1 (3.1, 5.1)	819	4.5 (4.2, 4.9)
IX(b) Fibrosarcomas, peripheral nerve & other fibrous	40	2.4 (1.7, 3.2)	260	1.4 (1.3, 1.6)
IX(c) Kaposi sarcoma	0	N/A[e]	11	0.1 (0.0, 0.1)
IX(d) Other specified soft tissue sarcomas	88	5.3 (4.2, 6.5)	888	4.9 (4.6, 5.3)
IX(e) Unspecified soft tissue sarcomas	15	0.9 (0.5, 1.4)	211	1.2 (1.0, 1.3)
X Germ cell & trophoblastic tumors & neoplasms of gonads	153	9.3 (7.8, 10.7)	2203	12.2 (11.7, 12.7)
X(a) Intracranial & intraspinal germ cell tumors	22	1.4 (0.8, 1.9)	342	1.9 (1.7, 2.1)
X(b) Extracranial & extragonadal germ cell tumors	25	1.5 (0.9, 2.1)	297	1.6 (1.4, 1.8)
X(c) Malignant gonadal germ cell tumors	91	5.5 (4.4, 6.6)	1447	8.0 (7.6, 8.5)
X(d) Gonadal carcinomas	10	0.6 (0.2, 1.0)	84	0.5 (0.4, 0.6)
X(e) Other and unspecified malignant gonadal tumors	5	0.3 (0.0, 0.6)	33	0.2 (0.1, 0.3)
XI Other malignant epithelial neoplasms and melanomas	245	14.9 (13.0, 16.7)	3032	16.9 (16.3, 17.5)
XI(a) Adrenocortical carcinomas	6	0.4 (0.1, 0.7)	47	0.3 (0.2, 0.3)
XI(b) Thyroid carcinomas	66	4.0 (3.0, 5.0)	1253	7.0 (6.6, 7.4)
XI(c) Nasopharyngeal carcinomas	15	0.9 (0.5, 1.4)	85	0.5 (0.4, 0.6)
XI(d) Malignant melanomas	91	5.5 (4.4, 6.7)	885	4.9 (4.6, 5.3)
XI(e) Skin carcinomas	<5	N/A[e]	16	0.1 (0.1, 0.1)
XI(f) Other and unspecified carcinomas	65	3.9 (3.0, 4.9)	746	4.2 (3.9, 4.5)
XII Other and unspecified malignant neoplasms	28	1.7 (1.1, 2.4)	98	0.5 (0.4, 0.7)
XII(a) Other specified malignant tumors	<5	N/A[e]	57	0.3 (0.2, 0.4)
XII(b) Other unspecified malignant tumors	26	1.6 (1.0, 2.2)	41	0.2 (0.2, 0.3)

[a] Childhood cancers classified by the International Classification of Childhood Cancers[15]

[b] Age-adjusted incidence rates per 1 million, based on OCCR data

[c] Age-adjusted incidence rates per 1 million, based on SEER data[42]

[d] Total includes children not classified by ICCC

[e] Fewer than 5 cases observed, data suppressed for confidentiality and stability reasons

[f] Also known as Wilms' Tumor

Table 2

Age-specific incidence rate per million for acute lymphoblastic leukemia, astrocytoma, and Hodgkin lymphoma in Oklahoma and the US, 1997-2012, ages 0-19

Age Group	Oklahoma Incidence Rate[a]	SEER Incidence Rate[a]	Rate Ratio (95% CI)
Acute Lymphoblastic Leukemia			
<1 year	19.9 (10.1, 29.6)	21.3 (18.3, 24.3)	0.93 (0.56, 1.55)
1 to 4 year	69.1 (60.0, 78.3)	77.5 (74.6, 80.4)	0.89 (0.78, 1.02)
5 to 9 years	37.3 (31.2, 43.3)	34.7 (33.0, 36.5)	1.07 (0.91, 1.27)
10 to 14 years	17.1 (13.0, 21.1)	21.6 (20.2, 22.9)	0.79 (0.62, 1.01)
15 to 19 years	17.5 (13.5, 21.5)	17.5 (16.3, 18.8)	1.00 (0.79, 1.27)
Astrocytoma			
<1 year	8.7 (2.3, 15.1)	12.6 (10.3, 14.9)	0.69 (0.32, 1.48)
1 to 4 year	14.6 (10.4, 18.8)	18.1 (16.7, 19.5)	0.81 (0.60, 1.09)
5 to 9 years	15.7 (11.8, 19.6)	15.1 (13.9, 16.2)	1.04 (0.80, 1.35)
10 to 14 years	11.4 (8.1, 14.7)	13.7 (12.6, 14.7)	0.83 (0.62, 1.12)
15 to 19 years	11.6 (8.3, 14.8)	10.4 (9.5, 11.3)	1.11 (0.83, 1.50)
Hodgkin Lymphoma			
<1 year	N/A[b]	N/A[b]	N/A[b]
1 to 4 year	N/A[b]	0.9 (0.6, 1.2)	N/A[b]
5 to 9 years	3.3 (1.5, 5.1)	4.3 (3.7, 4.9)	0.76 (0.43, 1.34)
10 to 14 years	9.2 (6.2, 12.1)	12.1 (11.1, 13.2)	0.75 (0.54, 1.05)
15 to 19 years	30.3 (25.0, 35.5)	30.5 (28.9, 32.1)	0.99 (0.83, 1.19)

[a] Incidence rates are unadjusted and per 1 million population

[b] Rates with fewer than 5 cases suppressed due to confidentiality and stability reasons

Table 3

Age-adjusted incidence rate per million and 95% confidence intervals of for acute lymphoblastic leukemia, astrocytoma, and Hodgkin lymphoma by race/ethnicity in Oklahoma and the US, 1997-2012, ages 0-19

	Oklahoma Incidence Rate[a] (95% CI)	SEER Incidence Rate[a] (95% CI)	Rate Ratio (95% CI)
Acute Lymphoblastic Leukemia			
White NH[b]	32.0 (28.6, 35.5)	34.1 (32.8, 35.3)	0.94 (0.84, 1.05)
African American NH	17.7 (11.4, 24.0)	16.7 (15.0, 18.4)	1.06 (0.73, 1.54)
American Indian/Alaska Native NH	40.3 (31.4, 49.2)	33.1 (26.3, 39.9)	1.22 (0.90, 1.65)
Hispanic	43.9 (34.2, 53.6)	44.5 (42.7, 46.3)	0.99 (0.79, 1.24)
Astrocytoma			
White NH	14.0 (11.7, 16.3)	17.7 (16.8, 18.6)	**0.79 (0.67, 0.94)**
African American NH	10.1 (5.3, 14.8)	11.2 (9.8, 12.6)	0.90 (0.55, 1.47)
American Indian/Alaska Native NH	11.0 (6.4, 15.6)	9.6 (5.9, 13.2)	1.15 (0.65, 2.03)
Hispanic	14.5 (8.8, 20.2)	10.3 (9.5, 11.2)	1.41 (0.94, 2.11)
Hodgkin Lymphoma			
White NH	11.7 (9.6, 13.8)	14.7 (13.9, 15.5)	0.83 (0.67, 1.02)
African American NH	5.4 (1.9, 8.9)	10.1 (8.8, 11.4)	0.50 (0.21, 1.23)
American Indian/Alaska Native NH	10.4 (5.9, 14.9)	4.7 (2.1, 7.2)	**3.78 (1.48, 9.67)**
Hispanic	11.5 (6.4, 16.5)	9.9 (9.0, 10.7)	1.39 (0.76, 2.54)

[a] Age-adjusted incidence rates per 1 million population

[b] NH: non-Hispanic

Table 4

Five-year observed survival proportions and 95% confidence intervals for childhood cancers in the US and Oklahoma from 1997-2012, ages 0-19[a]

Cancer Type	Oklahoma[b]	SEER[c]
Total[d]	77.0 (75.2, 78.9)	80.6 (80.2, 81.0)
I Leukemias, myeloproliferative & myelodysplastic diseases	75.9 (72.3, 79.6)	79.7 (78.9, 80.5)
I(a) Lymphoid leukemias	85.2 (81.7, 88.8)	85.2 (84.4, 86.0)
I(b) Acute myeloid leukemias	47.2 (37.7, 56.7)	58.5 (56.3, 60.7)
I(c) Chronic myeloproliferative diseases	71.4 (47.8, 95.1)	81.5 (76.8, 86.2)
I(d) Myelodysplastic syndrome/other myeloproliferative	N/A[e]	58.4 (47.2, 69.6)
I(e) Unspecified and other specified leukemias	68.0 (49.7, 86.3)	64.3 (58.2, 70.4)
II Lymphomas and reticuloendothelial neoplasms	85.1 (80.9, 89.3)	89.4 (88.6, 90.2)
II(a) Hodgkin lymphomas	91.7 (86.9, 96.4)	95.5 (94.7, 96.3)
II(b) Non-Hodgkin lymphomas (except Burkitt lymphoma)	74.7 (65.4, 84.0)	82.1 (80.3, 83.9)
II(c) Burkitt lymphoma	87.9 (76.7, 99.0)	87.5 (84.8, 90.2)
II(d) Miscellaneous lymphoreticular neoplasms	77.8 (58.6, 97.0)	84.4 (79.5, 89.3)
II(e) Unspecified lymphomas	88.9 (68.3, 100.0)	78.1 (68.9, 87.3)
III CNS and misc intracranial and intraspinal neoplasms	71.7 (67.2, 76.1)	72.5 (71.5, 73.5)
III(a) Ependymomas and choroid plexus tumor	80.0 (65.7, 94.3)	73.1 (69.6, 76.6)
III(b) Astrocytomas	71.6 (64.5, 78.7)	83.1 (81.9, 84.3)
III(c) Intracranial and intraspinal embryonal tumors	65.9 (56.0, 75.8)	62.7 (60.3, 65.1)
III(d) Other gliomas	51.0 (37.3, 64.7)	57.9 (55.2, 60.6)
III(e) Other specified intracranial/intraspinal neoplasms	89.4 (80.5, 98.2)	67.7 (58.9, 76.5)
III(f) Unspecified intracranial and intraspinal neoplasms	95.2 (86.1, 100.0)	38.1 (26.3, 49.9)
IV Neuroblastoma and other peripheral nervous cell tumors	58.4 (48.8, 68.0)	73.7 (71.7, 75.7)
IV(a) Neuroblastoma and ganglioneuroblastoma	58.2 (48.4, 67.9)	73.6 (71.6, 75.6)
IV(b) Other peripheral nervous cell tumors	N/A[e]	76.2 (64.8, 87.6)
V Retinoblastoma	92.9 (83.3, 100.0)	96.9 (95.7, 98.1)
VI Renal tumors	79.1 (70.8, 87.5)	88.1 (86.5, 89.7)
VI(a) Nephroblastoma/other nonepithelial renal tumors[f]	77.4 (68.4, 86.3)	89.1 (87.5, 90.7)
VI(b) Renal carcinomas	N/A[e]	75.1 (66.9, 83.3)
VI(c) Unspecified malignant renal tumors	N/A[e]	N/A[e]
VII Hepatic tumors	58.1 (40.7, 75.4)	62.3 (58.2, 66.4)
VII(a) Hepatoblastoma	59.1 (38.5, 79.6)	72.5 (68.0, 77.0)
VII(b) Hepatic carcinomas	50.0 (15.3, 84.7)	37.0 (29.2, 44.8)
VII(c) Unspecified malignant hepatic tumors	N/A[e]	N/A[e]
VIII Malignant bone tumors	69.2 (60.4, 77.9)	67.9 (65.9, 69.9)
VIII(a) Osteosarcomas	63.6 (50.9, 76.4)	65.6 (62.9, 68.3)

Cancer Type	Oklahoma[b]	SEER[c]
VIII(b) Chondrosarcomas	N/A[e]	93.9 (88.8, 99.0)
VIII(c) Ewing tumor and related sarcomas of bone	74.4 (60.7, 88.1)	66.4 (62.7, 70.1)
VIII(d) Other specified malignant bone tumors	N/A[e]	80.1 (72.5, 87.7)
VIII(e) Unspecified malignant bone tumors	62.5 (28.9, 96.1)	75.3 (61.2, 89.4)
IX Soft tissue and other extraosseous sarcomas	76.5 (69.3, 83.6)	71.2 (69.4, 73.0)
IX(a) Rhabdomyosarcomas	71.4 (57.8, 85.1)	63.8 (61.1, 66.5)
IX(b) Fibrosarcomas, peripheral nerve & other fibrous	73.9 (56.0, 91.9)	76.5 (71.8, 81.2)
IX(c) Kaposi sarcoma	N/A[e]	N/A[e]
IX(d) Other specified soft tissue sarcomas	81.0 (71.2, 90.7)	77.7 (75.3, 80.1)
IX(e) Unspecified soft tissue sarcomas	75.0 (45.0, 100.0)	68.3 (62.6, 74.0)
X Germ cell & trophoblastic tumors & neoplasms of gonads	89.0 (83.1, 94.9)	90.4 (89.2, 91.6)
X(a) Intracranial & intraspinal germ cell tumors	82.4 (64.2, 100.0)	85.8 (82.5, 89.1)
X(b) Extracranial & extragonadal germ cell tumors	86.7 (69.5, 100.0)	81.8 (77.9, 85.7)
X(c) Malignant gonadal germ cell tumors	96.8 (92.4, 100.0)	94.7 (93.7, 95.7)
X(d) Gonadal carcinomas	70.0 (41.6, 98.4)	73.2 (63.8, 82.6)
X(e) Other and unspecified malignant gonadal tumors	60.0 (17.1, 100.0)	77.5 (65.2, 89.8)
XI Other malignant epithelial neoplasms and melanomas	88.3 (83.5, 93.1)	91.4 (90.4, 92.4)
XI(a) Adrenocortical carcinomas	N/A[e]	56.6 (42.3, 70.9)
XI(b) Thyroid carcinomas	100.0 (100.0, 100.0)	98.6 (98.0, 99.2)
XI(c) Nasopharyngeal carcinomas	66.7 (40.0, 93.3)	86.9 (80.8, 93.0)
XI(d) Malignant melanomas	98.6 (95.8, 100.0)	94.6 (93.4, 95.8)
XI(e) Skin carcinomas	N/A[e]	100.0 (100.0, 100.0)
XI(f) Other and unspecified carcinomas	72.5 (58.7, 86.3)	77.2 (74.5, 79.9)
XII Other and unspecified malignant neoplasms	80.0 (64.3, 95.7)	80.7 (74.0, 87.4)
XII(a) Other specified malignant tumors	N/A[e]	80.7 (72.5, 88.9)
XII(b) Other unspecified malignant tumors	78.3 (61.4, 95.1)	80.3 (68.7, 91.9)

[a] Childhood cancers classified by the International Classification of Childhood Cancers[15]

[b] Based on OCCR data

[c] Based on SEER data[42]

[d] Total includes children not classified by ICCC

[e] Fewer than 5 cases observed, data suppressed for confidentiality and stability reasons

[f] Also known as Wilms' Tumor

Table 5

Five-year observed survival (95% confidence intervals) for acute lymphoblastic leukemia, astrocytoma, and Hodgkin lymphoma by race/ethnicity for Oklahoma, 1997-2012, ages 0-19

	ALL	Astrocytoma	Hodgkin Lymphoma
Race/Ethnicity	**Percent (95% CI)**	**Percent (95% CI)**	**Percent (95% CI)**
White NH[a]	86.0 (81.6, 90.3)	73.4 (65.1, 81.7)	91.8 (86.3, 97.2)
African American NH	70.8 (52.6, 89.0)	50.0 (23.8, 76.2)	83.3 (53.5, 100.0)
American Indian/Alaska Native NH	82.0 (72.3, 91.6)	87.5 (71.3, 100.0)	94.4 (83.9, 100.0)
Hispanic	92.0 (84.5, 99.5)	62.5 (38.8, 86.2)	100.0 (100.0, 100.0)

[a]NH: non-Hispanic